# MONITORING EQUIPMENT

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Monitoring equipment can be useful to measure the actual operating parameters of various energy equipment and compare them with the design parameters to determine if energy efficiency can be improved. Or monitoring equipment can be used to identify measure steam or compressed air leaks. Parameters that are often monitored during an energy assessment are:

- Basic electrical parameters in AC & DC systems: voltage (V), current (I), power factor, active power (kW), maximum demand (kVA), reactive power (kVAr), energy consumption (kWh), frequency (Hz), harmonics, etc.
- Other non-electrical parameters: temperature and heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, total dissolved solids (TDS), pH, moisture content, relative humidity, flue gas analysis ($CO_2$, $O_2$, CO, $SO_x$, $NO_x$), combustion efficiency, etc.

This module provides information for various monitoring equipment that are often used during energy assessments in industry:

1. Electrical measuring instruments
2. Combustion analyzer
3. Thermometers
4. Manometers
5. Water flow meters
6. Tachometers / Stroboscopes
7. Leak detectors
8. Lux meters

For each type of monitoring equipment the following information is given:

- What the monitoring equipment does
- Where the monitoring equipment is used
- How to operate the monitoring equipment
- Precautions and safety measures necessary for the monitoring equipment

# 1. ELECTRICAL MEASURING INSTRUMENTS

## 1.1 What electrical measuring instruments do

Electrical measuring instruments include clamp-on or power analyzers and are used to measure main electrical parameters such as KVA, kW, PF, Hertz, KVAr, Amps and Volts. Some of these instruments also measure harmonics. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.

There are several models available in the market from different companies. One such instrument is the HIOKI 3286-20 Clamp-on Power Hitester (Figure 1). It measures the following parameters:

- Voltage: 150 V to 600 V, 3 ranges
- Current: 200 A or 1000 A, 2 ranges
- Voltage/current peak
- Effective/reactive/apparent power (single-phase or 3-phase): 30 kW to 1200 kW, 14 combination patterns
- Power factor
- Reactivity
- Phase angle
- Frequency,
- Phase detection (3-phase)
- Voltage/current harmonic levels (up to 20th)

**Figure 1. Hioki 3286-20 Clamp-on Power Hitester** (Hioko Ltd.)

## 1.2 Where electrical measuring instruments are used

These instruments are applied on-line to measure various electrical parameters of motors, transformers, and electrical heaters. There is no need to stop the equipment while taking the measurements.

## 1.3 How to operate electrical measuring instruments

The instrument has three leads (wires), which are connected to the crocodile clips at the end. The three leads are yellow, black and red. Figures 2 to 8 give illustrate the measurement method for various conditions. However, operating procedures may vary for different types of clamp-on or power analyzers. For the correct operation procedure the operator should always check the instruction manual supplied with the instrument.

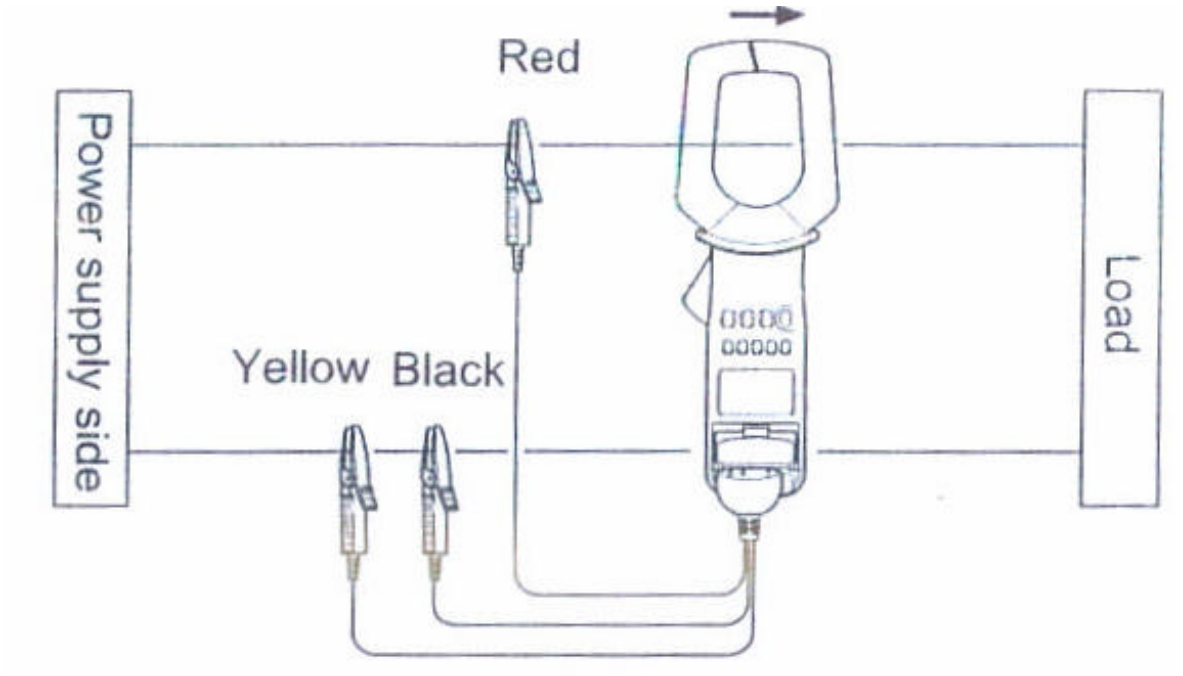


**Figure 2. Power Measurement on Single-phase Two-wire Circuit** (Hioki Ltd)

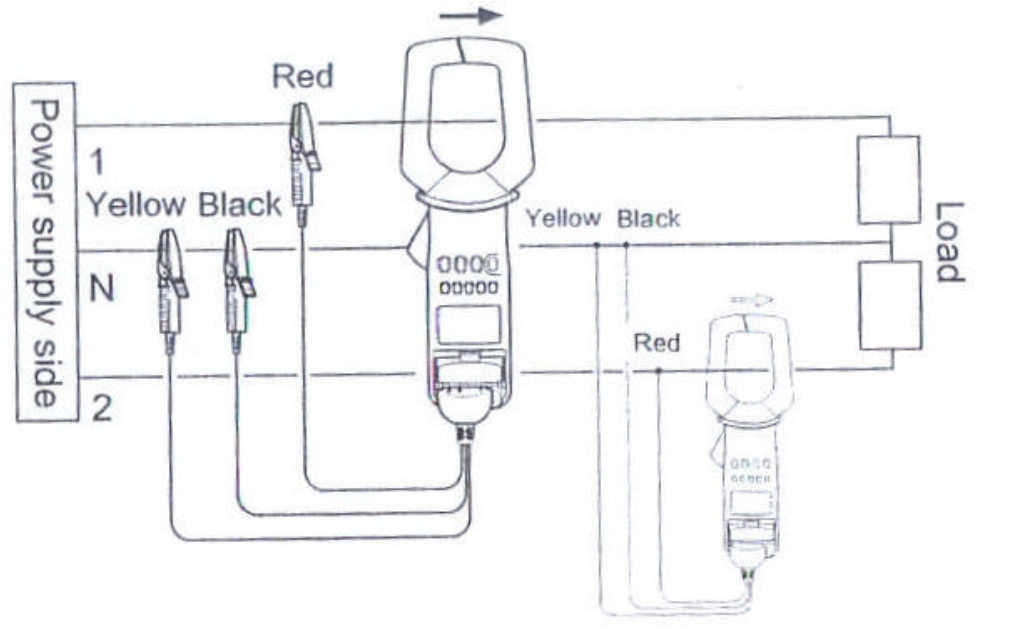


**Figure 3. Power and Power Factor Measurement on Single-phase Three-wire Circuit**
(Hioki Ltd)

*The power and power factor of a single-phase three-wire circuit are measured similarly to a single-phase two-wire circuit. Connect the black lead to the neutral wire as shown, and then switch the red lead and clamp sensor to the respective wires. Now the power and power factor between the wires can be measured.*

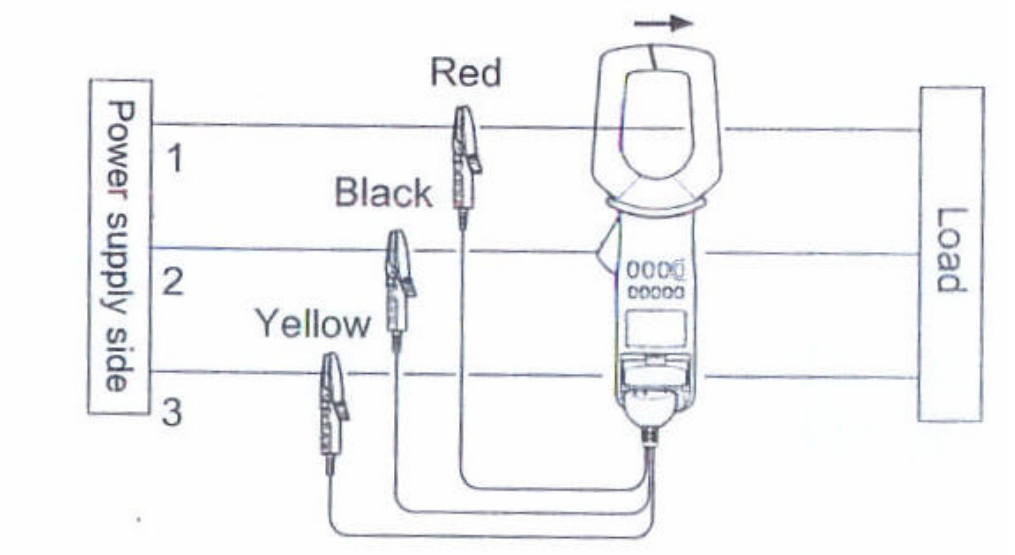


**Figure 4. Power and Power Factor Measurement on Three-phase Three-wire Circuit** (Hioki Ltd)

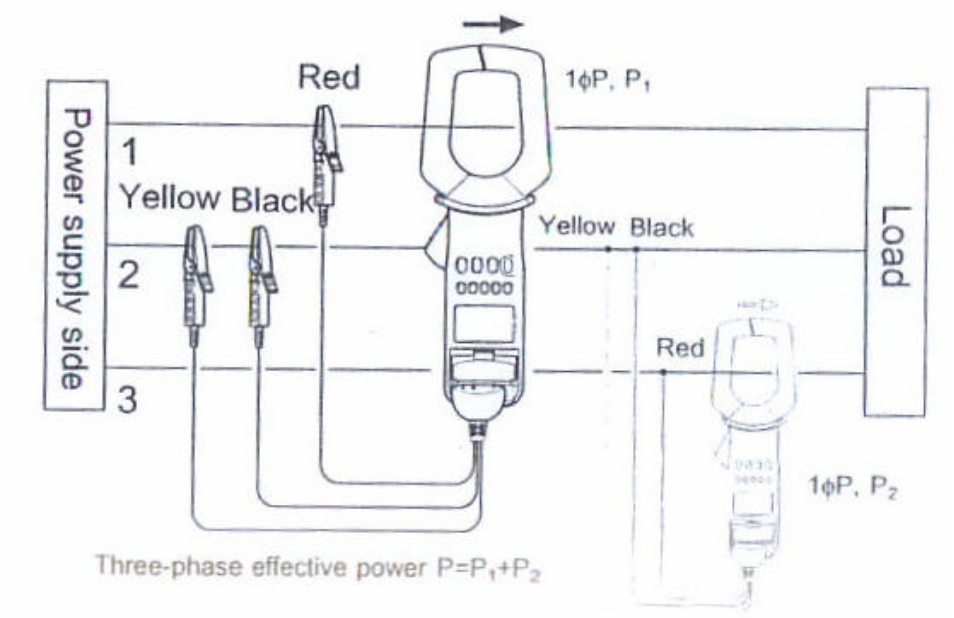


**Figure 5. Alternative Method of Power and Power Factor Measurement on Three-phase Three-wire Circuit** (Hioki Ltd)

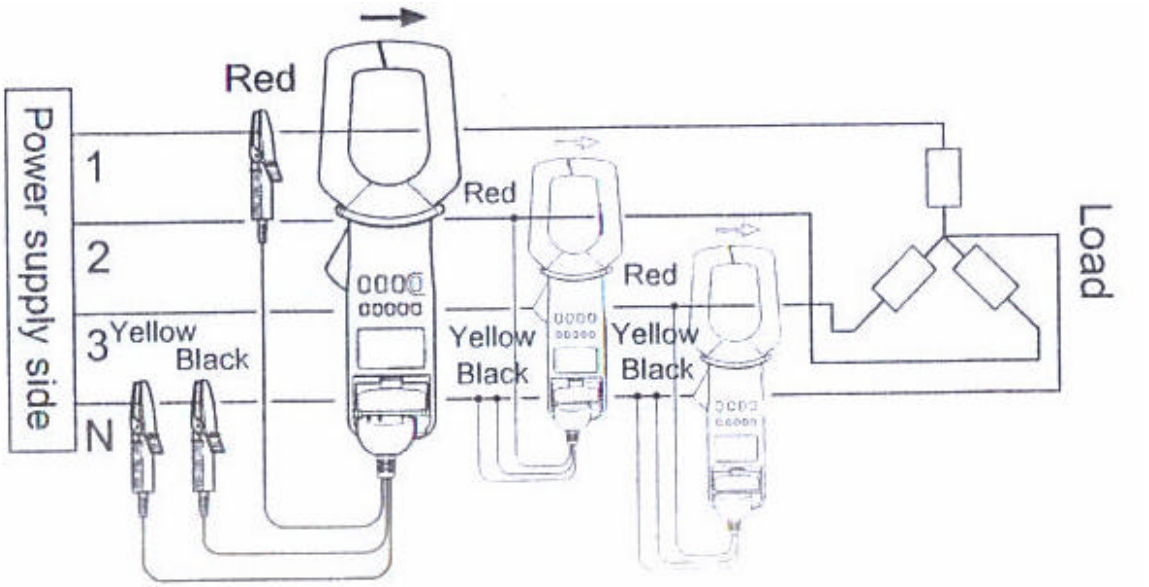


**Figure 6. Power and Power Factor Measurement on Three-phase Four-wire Circuit** (Hioki Ltd)

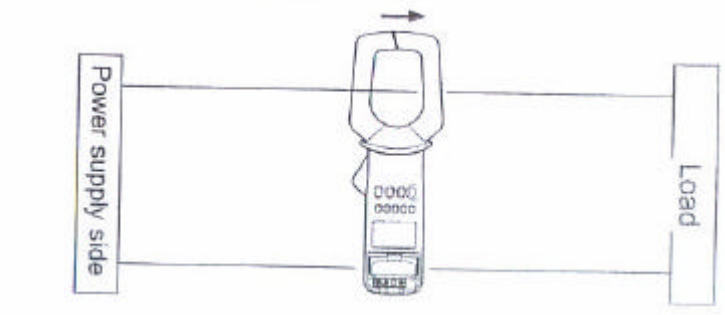


**Figure 7. Current Measurement** (Hioki Ltd)

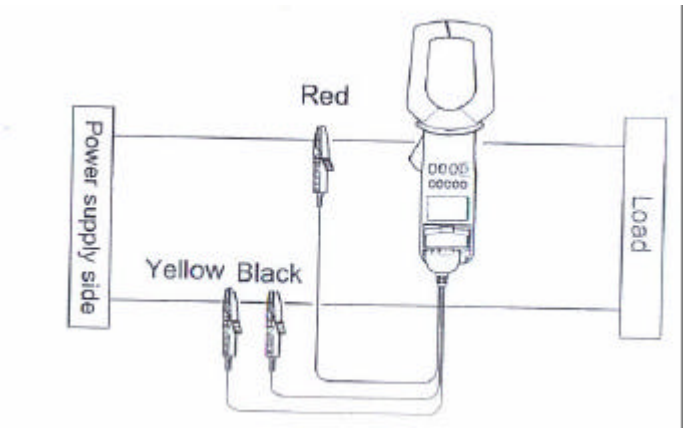


**Figure 8. Voltage Measurement** (Hioki Ltd)

## 1.4 Precautions and safety measures

Some precautions and safety measures to be taken while using clamp-on and power analyzers are:

- To avoid short circuits and potentially life-threatening hazards, never attach the clamp to a circuit that operates at more than the maximum rated voltage, or over bare conductors.
- The clamp-on probe should be connected to the secondary side of a breaker, so the breaker can prevent an accident if a short circuit occurs.
- While using the instrument, use rubber hand gloves, boots, and a safety helmet, to avoid electrical shocks, and do not use the instrument when hands are wet.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 2. COMBUSTION ANALYZERS

## 2.1 What a combustion analyzer does

A combustion analyzer is used to measure the composition of the flue gases after combustion has taken place. Different combustion analyzers can be ordered to match the requirements at a plant. Basically all combustion analyzers measure the percentage oxygen ($O_2$) or carbon dioxide ($CO_2$) in the exit flue gases and then use an inbuilt programme to calculate the combustion efficiency if required. The various types of combustion analyzers are given below:

**Fuel Efficiency Monitor**

This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency

**Fyrite**

A hand bellow pump draws the flue gas sample into a solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. The percentage oxygen or $CO_2$ can be read from the scale.

**Gas Analyzer**

This instrument has in-built chemical cells which measure various gases such as $CO_2$, CO, $NO_X$, $SO_X$ etc.

## 2.2 Where a combustion analyzer is used

Combustion analyzers are used to determine the composition of the flue gases in the duct. The duct is the large piping arrangement of rectangular configuration and is used to flush out the combusted gases to the chimney. The values for the different components of the flue gases are volume-based. Mostly these instruments measure the percentage oxygen and carbon dioxide and the temperature of the flue gas. During energy audits it is desirable to know the composition of the flue gases in order to assess the combustion conditions and efficiency and leakages of atmospheric air into the system.

## 2.3 How to operate

Different types of the combustion analyzers are operated differently. For all types of combustion analyzers the probe is inserted into the duct through a small hole made in the duct for monitoring purposes. In case of a fyrite combustion analyzer, which is manually operated, the flue gas from the duct is sucked out using a manual pumping device. In most of the other analyzers the flue gases are pumped out of the ducts using a suction pump. The collected gases react with the chemical/cells and give readings of % oxygen or carbon dioxide.

## 2.4 Precautions and safety measures

Some precautions and safety measures to be taken while using combustion analyzers are:

- Always calibrate the instrument in open fresh air before taking a set of measurements.
- Check for the clogging of the air filters of the instrument.
- During measurements, ensure that the rubber tubing carrying the gases from the duct to the instrument is not bent.
- After insertion of the probe into the duct, care should be taken to wrap the left opening space with cotton rags to ensure that there is no filtration of air into the system or air escaping the system.
- Thick cotton hand gloves, goggles, a safety helmet and other safety gear should be worn before taking the readings. Remember that the gases you are handling are very hot!
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 3. MANOMETERS

## 3.1 What a manometer does

Manometers are widely used instrument in energy audits for measuring the differential pressure across two points. The oldest type is the liquid-column manometer. A very simple version of a liquid-column manometer is a U-shaped tube (see Figure 9) that is half-full of liquid (usually oil, water or mercury) where the measured pressure is applied to one side of the tube whilst the reference pressure (which might be that of the atmosphere) is applied to the other. The difference in liquid level represents the applied pressure.

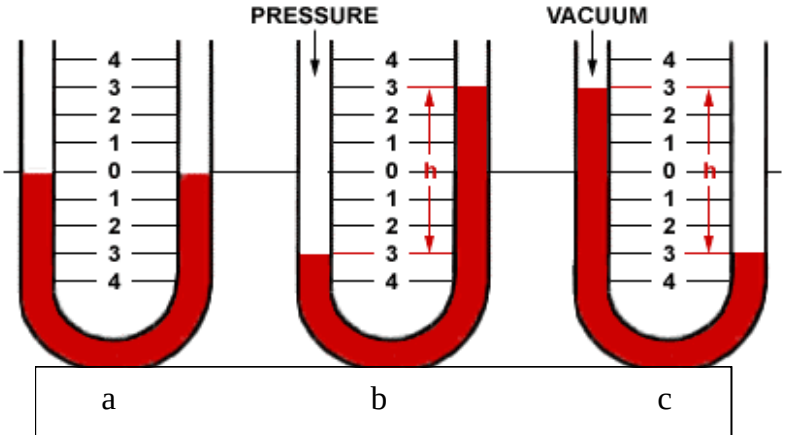


**Figure 9. Schematic illustration of a liquid-column manometer**
(Dwyer Instruments Inc.)

The principles of how a manometer works are as follows:

- Figure 9a. In its simplest form the manometer is a U-tube about half filled with liquid. With both ends of the tube open, the liquid is at the same height in each leg.
- Figure 9b. When positive pressure is applied to one leg, the liquid is forced down in that leg and up in the other. The difference in height, "h," which is the sum of the readings above and below zero, indicates the pressure.
- Figure 9c. When a vacuum is applied to one leg, the liquid rises in that leg and falls in the other. The difference in height, "h," which is the sum of the readings above and below zero, indicates the amount of vacuum.

There are three main types of manometers:

- Single-limb liquid-column manometer has a larger reservoir instead of one side of the U-tube and has a scale beside the narrower column. This column can further amplify the liquid movement. Liquid-column manometers can be used to measure small differences between high pressures.
- Flexible Membrane Type: This type uses the deflection of a flexible membrane that seals off a volume with a fixed reference-pressure. The degree of deflection of the membrane corresponds with a specific pressure. Reference tables exist to determine the pressure for different deflections.

- Coiled Tube Type: A third variant uses a coiled tube which will expand with increasing pressure. This causes a rotation of an arm connected to the tube.

## 3.2 Where the manometer is used

During conducting of energy audit studies manometers are used to determine the differential pressure between two points in a duct carrying exhaust gases or air. The pressure differential is then used to calculate the velocity of flow in the duct using the Bernoulli's equation. ( Pressure Differential = $v^2/2g$). A more detailed account of use of manometer is given in section on hoe to operate a manometer. However the same can be used for measuring the differential pressure across two points in a pipe carrying any fluid. In this case the precaution to be taken is that the manometer should be compatible to be used for fluid flows. The velocity of flow of fluid is given by Differential pressure = $f\ LV^2/2gD$ where f is the friction factor of the pipe material, L is distance between two points across which pressure differential is taken, D is the diameter of the pipe and g is the gravitational constant.

## 3.3 How to operate a manometer

It is not easy to explain one way of operating manometers. The reason is that there are many different kinds of manometers that require different ways of handling.

However, some operating steps are the same. During energy audits, air velocity in ducts can be measured using a pitot tube and flows are calculated using a manometer. A sampling hole is made in the duct (pipe carrying exhaust gases) and the pitot tube is inserted into the duct. The two openings at the end of the pitot tube are connected to the two openings of the manometer. The difference in level of the manometer gives the total velocity pressure. For example, in case of a digital manometer the readings are displayed as mm of the water column.

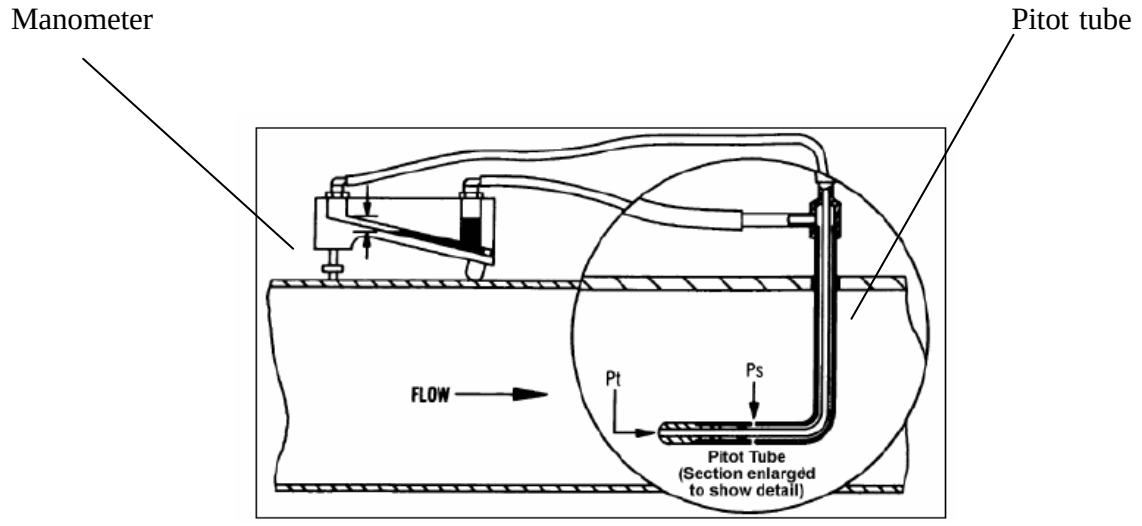


**Figure 10. Measurement using Pitot Tube and Manometer**
(Dwyer Instruments Inc.)

## 3.4 Precautions and safety measures

- Manometers should not be exposed to very high pressures. In case of high pressures inclined tune manometers should be used.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 4. THERMOMETERS

## 4.1 What a thermometer does

Thermometers are instruments used to measure the temperature of fluids, surfaces or gases, for example of the flue gases after combustion has taken place. Thermometers are classified as contact thermometers or non-contact or infrared thermometers and are described below.

**Contact thermometer**
There are many types of contact thermometers. A simple clinical thermometer is the best known example of a contact thermometer. However, for the purpose of energy audits in an industrial plant we generally use thermocouples for measuring temperatures with a high accuracy. It consists of two dissimilar metals, joined together at one end. The thermocouple metal alloys are commonly available as wire. A thermocouple is available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. There are high temperature calibrations R, S, C and GB. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple. Although the thermocouple calibration dictates the temperature range, the maximum range is also limited by the diameter of the thermocouple wire.

**Figure 11. Thermocouple Thermometer**
(Reliability Direct, Inc)

**Non-contact or infrared thermometer**
A non-contact or infrared thermometer allows the measurement of temperatures without physical contact between the thermometer and the object of which the temperature is determined. The thermometer is directed at the surface and immediately gives a temperature reading. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.

Infrared thermometer allows users to measure temperature in applications where conventional sensors cannot be used or cannot produce accurate temperature readings, such as:

- When a fast response or measurement is required, such as moving objects (i.e. rollers, moving machinery, or a conveyor belt)
- Where non-contact measurements are required because of contamination or hazardous reasons (such as high voltage)
- Too large distances or heights
- Too high temperatures for thermocouples or other contact sensors
- The object is contained in a vacuum or other controlled atmosphere
- The object is surrounded by an electromagnetic field (such as induction heating)

The basic principle of the infrared thermometer is that all objects emit infrared energy. The hotter an object, the more active its molecules are, and the more infrared energy it emits. An infrared thermometer contains a lens that focuses the collected infrared energy from the object onto a detector. The detector converts the energy into an electrical signal, which is amplified and displayed in units of temperature after corrections for ambient temperature variations.

**Figure 12. Non-contact or Infrared Thermometer**
(Nitonuk Ltd. 2003)

## 4.2 Where the thermometer is used

In energy audits, the temperature is one of the most important parameters to be measured in order to determine the thermal energy loss or to make a thermal energy balance. Temperature measurements are taken for the audit of air conditioning units, boilers, furnaces, steam systems, waste heat recovery systems, heat exchangers, etc. During the audits, the temperature can be measured of the:

- Ambient air
- Chilled water in refrigeration plants
- Inlet air into the Air Handling unit of AC plant
- Cooling water inlet and out let at the Cooling Tower

- Surfaces of steam pipelines, boilers, kilns
- Input water to the boiler
- Exhaust gases
- Condensate returned
- Pre heated air supply for combustion
- Temperature of the fuel oil

## 4.3 How to operate a thermometer

The thermocouple (contact thermometer) consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. A probe is inserted into a liquid or gaseous stream to measure the temperature of, for example, flue gas, hot air, or water. A leaf type probe is used to measure surface temperatures. In most of the cases the thermocouple directly gives the reading in the desired units( Centigrade or Fahrenheit) on a digital panel.

The operation of a non-contact or infrared thermometer is simple. The infrared thermometer (gun) is pointed towards the surface where the temperature must be measured. The measurement result is read directly from the panel.

## 4.4 Precautions and safety measures

The following precautions and safety measures apply when using a thermometer:

- The probe must be immersed in the fluid and the measurement must be taken after 1-2 minutes, i.e. after the stabilization of the readings.
- Before using the thermocouple, the temperature range for which the thermocouple is designed for should be checked.
- The probe of the thermocouple should never touch the bare flame.
- Before using a non-contact thermometer the emissivity should be set in accordance with the surface where the temperature is to be measured.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 5. WATER FLOW METERS

## 5.1 What a water flow meter does

A flow meter is an instrument used to measure the linear, nonlinear, mass or volumetric flow rate of a liquid or a gas. This section deals specifically with water flow meters. The choice of method or type of water flow meter depends on the site conditions and the required measurement accuracy.

Apart from water flow meters, there are several methods available to measure water flow during an audit. Two common methods to obtain reasonably accurate estimates of the water flow are:

- **Time of fill method:** Water is allowed to fill a known volume of a vessel or tank ($m^3$). The time taken to fill up this volume is recorded using a stop watch (seconds). The volume divided by the time gives the average flow in $m^3$/sec.
- **Float method**: This method is generally used to measure the flow in an open channel. A specific distance (for example 25 meters or 50 meters) is marked on the side of the channel. A ping-pong ball is placed on the water and the time it takes for the ball to float to the marked distance is recorded. Multiple readings are taken to get a more accurate timing. The velocity of the water is calculated by Distance traveled by the ball / Average time taken. Depending on the flow conditions and the site characteristics the calculated velocity is further divided by a factor 0.8 to 0.9 to obtain the peak velocity in an open channel, since the velocity at the surface is reduced due to drag forces of the wind etc.

Some of the most common types of flow meters are given below:

**Rotameter or variable area flow meter for gases and liquids.**
The rotameter consists of a tapered tube and a float. It is the most widely used variable-area flow meter because of its low cost, simplicity, low pressure drop, relatively wide range ability, and linear output.

**Figure 13. Rotameter** (Omega Engineering Ltd)

**Variable flow meters - spring and piston flow meters for gases and liquids.**
Piston-type flow meters use an annular orifice formed by a piston and a tapered cone. The piston is held in place at the base of the cone (in the "no flow position") by a calibrated spring. Scales are based on specific gravities of 0.84 for oil meters and 1.0 for water meters. Their simple design and the ease with which they can be equipped to transmit electrical signals has made them an economical alternative to rotameters for flow rate indication and control.

**Figure 14. Spring and Piston Flow Meters**
(Omega Engineering Ltd)

**Ultrasonic flow meters (Non-Intrusive or Doppler) for Liquids**
Ultrasonic doppler flow meters are commonly used in dirty applications such as wastewater and other dirty fluids and slurries which ordinarily cause damage to conventional sensors. The basic principle of operation employs the frequency shift (Doppler Effect) of an ultrasonic signal when it is reflected by suspended particles or gas bubbles (discontinuities) in motion.

**Figure 15. Ultrasonic Flow Meter** (Dynasonics Ltd)

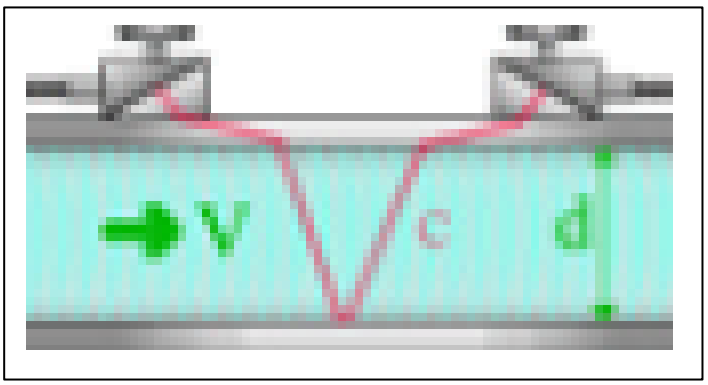


**Figure 16. How an Ultrasonic Flow Meter works**
(Eesiflow International Pty Ltd.)

**Turbine flow meters**
The turbine meter is a very accurate meter (0.5% of the reading) and can be used for clean liquids and viscous liquids up to 100 centistokes. A minimum of 10 pipe diameters of straight pipe is required on the inlet. The most common outputs are a sine wave or square wave frequencies, but signal conditioners can be placed on the top of the meter for analog outputs and explosion proof classifications. The meters consist of a multi-bladed rotor mounted at right angles to the flow and suspended in the fluid stream on a free-running bearing.

**Paddlewheel sensors**
Paddlewheel sensors are one of the most popular cost effective flow meters for water or water-like fluids. Many are offered with flow fittings or insertions styles. These meters, like the turbine meter, require a minimum of 10 pipe diameters of straight pipe on the inlet and 5 on the outlet. Chemical compatibility should be verified when not using water. Sine wave and square wave pulse outputs are typical but transmitters are available for integral or panel mounting. The rotor of the paddlewheel sensor is perpendicular to the flow and is in contact with only a limited cross section of the flow.

**Positive displacement flow meters**
These meters are used for water applications when no straight pipe is available and when turbine meters and paddlewheel sensor would cause too much turbulence. The positive displacement flow meters are also used for measuring the flow of viscous liquids.

**Vortex meters**
The main advantages of vortex meters are their low sensitivity to variations in process conditions and low wear relative to orifices or turbine meters. Also, initial and maintenance costs are low. For these reasons, they have are widely accepted by users. Vortex meters do require sizing.

**Magnetic flow meters for conductive liquids**
These flow meters are available in in-line or insertion style. The magnetic flow meters do not have any moving parts and are ideal for measuring the flow of wastewater or any dirty liquid that

is conductive. Displays are integral or an analog output can be used for remote monitoring or data logging.

## 5.2 Where the water flow meter is used

During energy audits, water flow measurements are of significant importance. Generally the measurements are taken to quantify the amount of liquid/water flowing in a pipe. If there is no flow measurement device attached to the pipe line, then the flow can be quantified using an ultrasonic flow meter. Typical cases where the measurement of the water flow is absolutely essential are as part of determining the efficiency of pumps, the efficiency of cooling towers, chillers and air conditioning plants, heat exchangers, and condensers.

## 5.3 How to operate water flow meters

There are many varieties of the ultrasonic flow meters available on the market. The functioning of each model differs from the other. However the basic principle of all remains same. The 2 probes/sensors of the ultrasonic flow meters are placed on the surface of the pipe at some distance apart along a straight line. The diameter of the pipe determines the distance between the probes. When the meter is turned on, it generates sonic waves which are transmitted via one of the probes/sensors and are received by the other. The meter is calibrated to display the velocity or volume of the flow of liquid inside the pipe, based on the time required by the sonic waves to travel the distance from one sensor to the other.

## 5.4 Precautions and safety measures

The following precautions should be taken when using water flow meters:

- The probes/sensors should be placed on the surface of the pipes after thorough cleaning of the spot. Care should be taken that there is no speck of paint etc. Ideally the spot where the sensors are placed should be filed by a emery paper.
- The meter would not give the measurements if the internal condition of the pipe is corroded or has any alga growth.
- The measurement should be taken where the pipe flow is expected to be laminar and the pipe must be flowing full.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 6. TACHOMETERS / STROBOSCOPES

## 6.1 What tachometers and stroboscopes do

In any audit exercise speed measurements of for example motors are critical as they may change with frequency, belt slip and loading. There are two main types of speed measurement instruments: the tachometer and the stroboscope.

**Figure 17. A tachometer (left) and a stroboscope (right)** (Reliability Direct, Inc)

**Tachometer**
A simple tachometer is a contact type instrument, which can be used to measure speeds where direct access is possible.

**Stroboscope**
More sophisticated and safer instruments to measure speed are non-contact instruments, such as stroboscopes. A stroboscope is a source of flashing light that can be synchronized with any fast, repetitive motion so that a rapidly moving device seems to stand still, or to move slowly.

To illustrate this principle, consider the following example: Assume a white disk with a single black dot mounted on the shaft of an 1800-rpm motor. When the disk is rotating at 1800 rpm, it is impossible for the human eye to distinguish a single image and the dot will appear to be a blurred continuous circle. When illuminated by the flashing stroboscope light, synchronized to flash once every revolution of the disk (when the dot is at 3 o'clock, for example), the dot will be seen at this position - and only at this position - at a rate of 1800 times each minute. Thus, the dot will appear to "freeze" or stand still.

If the flash rate of the stroboscope is slowed to 1799 flashes per minute, the dot will be illuminated at a slightly different position each time the disc revolves, and the dot will appear to

move slowly in the direction of rotation through 360° and arrive at its original position 1 minute later. A similar movement, but in a direction opposite the rotation of the dot, will be observed if the flash rate of the stroboscope is increased to 1801 fpm. If desired, the rate of apparent movement can be speeded up by further increases or decreases in the strobe flash rate.

When the image is stopped, the flash rate of the strobe equals the speed of the moving object. And since the flash rate is known the speed of the object is also known. Thus the stroboscope has a dual purpose of measuring speed and of apparently slowing down or stopping rapid motion for observation. The practical significance of the slow-motion effect is that, since it is the true copy of the high speed motion, all irregularities (vibration, torsion, chattering, whip) present in the high speed motion can be studied.

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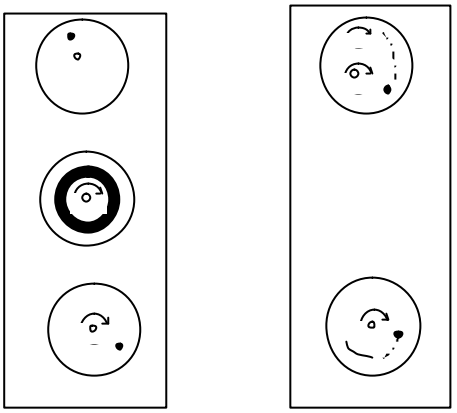

**Figure 18. Principle of the Working of a Stroboscope**
(NPC, 2006)

For audit studies we generally use contact type of tachometers since they are readily available.

## 6.2 Where tachometers and stroboscopes are used

Tachometers and stroboscopes are used measure the speed of rotation of motors, fans, pulleys etc.

## 6.3 How to operate a tachometer and stroboscope

In a contact-type tachometer, the wheel of the tachometer is brought in contact with the rotating body. Due to friction between the two, after few seconds the speed of the wheel of the tachometer is the same as the speed of the rotating body. This speed is displayed on the panel as rpm.

The digital stroboscope is a versatile flashing light source that is used to measure the speed of fast-moving objects or to produce the optical effect of stopping or slowing down high-speed motion for purposes of observation, analysis, or high-speed photography. The stroboscope emits a high-intensity, short-duration flash of light. The instrument features an electronic pulse

generator that controls the flash rate, a line-operated power supply, and a light-emitting diode (LED) readout in flashes per minute. The light can be aimed at most moving objects, including those in otherwise inaccessible areas. When measuring the rotational speed of an object, set the flash rate initially to a higher setting than the estimated speed of the object. Then, slowly reduce the flash rate until the first single image appears. At this point, the strobe flash rate is equal to the rotational speed of the object, and the speed can be read directly from the digital display.

## 6.4 Precautions and safety measures

The following precautions should be taken when using a tachometer and stroboscopes:

- Care should be taken while bringing the wheel of the tachometer in contact with the rotating body.
- From a safety point of view never wear loose clothing when taking measurements with tachometers.
- Avoid being alone when taking measurements.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 7. LEAK DETECTORS

## 7.1 What leak detectors do

As the name implies, ultrasonic leak detectors detect the ultrasonic sound of a leak. You are probably familiar with the hissing sound a large leak makes. Smaller leaks also emit a sound, however the frequency is too high for our ears to detect it. An ultrasonic leak detector transforms the ultrasonic hissing sound to a sound that humans can hear, and thus leads to the source of the leak.

**Figure 19. Leak Detectors** (Reliability Direct, Inc)

Some other information about ultrasonic leak detectors includes:

- **Distance and access**. Some leaks can be heard from a several meters away, therefore access to the leak is not always necessary. As long as the leak is turbulent, there will be enough sound that can be detected ultrasonically.
- **Pressure.** High pressure of leaks is not necessary. Ultrasonic can detect pinhole leaks with a pressure as low as 1 psi. However, the more pressure behind the leak, the easier it will be to locate.
- **Sensitivity to sound.** Ultrasonic leak detectors are very sensitive to sound. A good ultrasonic leak detector can actually let you hear the blink of the human eye. A leak test can be done in an enclosed area which is saturated with refrigerant, and the only indication an ultrasonic will give you is the sound of the leak. A good ultrasonic detector uses an electronic process called "heterodyning" to convert this high frequency leak sound to a lower range where the hissing of the leak can be heard through a set of headphones, and traced to its source. Any turbulent gas will generate ultrasound when it leaks, therefore it does not matter what refrigerant you are leak testing. Ultrasonic detectors will even detect air as it rushes into a system under vacuum.
- **Background noises.** Because the ultrasonic detector is focused on a specific band/frequency of sound, it will not detect wind, voices, traffic, and most normal operational sounds. However, larger systems with a multitude of pressure regulating valves and high velocity flow may produce hissing sounds at frequencies where ultrasonic detectors are most

sensitive. In this case it would be necessary to shut the system down, or use another method of detecting leaks.

- **Choice of leak detector.** Always consider the capabilities and the limitations of the leak detection method used. It is thereby important to consider more than just the sensitivity under laboratory / testing conditions when choosing a leak detector. For example, a highly sensitive "sniffer" type was able to detect a leak of 0.25oz. of refrigerant per year in a controlled laboratory setting. But the leak detector would give different results when used on the windy and dirty rooftop where you might be trying to find refrigerant leaks.

## 7.2 Where leak detectors are used

Ultrasonic leak detectors are used to detect leaks of compressed air and other gases which are normally not possible to detect with the human ear.

No leak detector will find every leak, every time. It is often a combination of several available methods which will insure the highest rate of success.

## 7.3 How to operate a leak detectors

It is not easy to generalize the operating method of a leak detector. The reason is that there are many different kinds of leak detectors that require different ways of handling. However, some steps are the same:

- The probe of the ultrasonic leak detector instrument is placed near the gas/steam pipe line where a leak is suspected
- The headphone attached to the instrument is placed on the ears
- The probe is moved slowly until the person can hear a hissing sound through headphone, indicating a leak
- The position is marked to identify the location of the leakage

## 7.4 Precautions and safety measures

The following measures should be taken when using ultrasonic leak detectors:

- Dust or smoke should not be coming out of the pipe, otherwise dust/smoke will choke the probe and leads to the instrument failure
- Avoid measurement at the places where sound levels are high
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

# 8. LUX METERS

## 8.1 What lux meters do

Lux meters are used to measure illumination (light) levels.

Most lux meters consist of a body, a sensor with a photo cell, and a display panel. The sensor is placed under the light source. The light that falls on the photo cell has energy, which is transferred by the photo cell into electric current. The more light is absorbed by the cell, the higher the generated current. The meter reads the electrical current and calculates the appropriate value of either Lux or Foot candles. This value is shown on the display panel.

A key thing to remember about light is that it is usually made up of many different types (colors) of light at different wavelengths. The reading, therefore, is a result of the combined effects of all the wavelengths. A standard color can be referred to as color temperature and is expressed in degrees Kelvin. The standard color temperature for calibration of most light meters is 2856 degrees Kelvin, which is more yellow than pure white. Different types of light bulbs burn at different color temperatures. Lux meter readings will, therefore, vary with different light sources of the same intensity. This is why some lights seem "harsher" or "softer" than others.

**Figure 20. Lux Meters** (Reliability Direct, Inc)

## 8.2 Where lux meters are used

Lux meters are used to measure illumination levels in offices, factories etc.

## 8.3 How to operate a lux meters

This instrument is very simple to operate. The sensor is to be placed at the work station or at the place where intensity of the light is to be measured, and the instrument will directly give the reading on the display panel.

## 8.4 Precautions and safety measures

The following measures should be taken when working with lux meters:

- The sensor is to be properly placed on the work station to obtain an accurate reading
- Due to the high sensitivity of sensor it should be stored safely
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

## 9. REFERENCES

The text for this chapter is based on the section with information on energy equipment from the *Energy Manager Training* website, with kind permission from India's Bureau of Energy Efficiency, supplemented with field experience from the National Productivity Council of India. www.energymanagertraining.com/energy_audit_instruments/new_energy_audit_equipment.htm

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